Lithographic Apparatus and Device Manufacturing Method

[0001] This application claims priority from European patent applications EP 02257822.3, filed November 12, 2002, EP 03253636.9, filed June 9, 2003, and EP 03254059.3, filed June 26, 2003, all herein incorporated in their entirety by reference.

Field

[0002] The present invention relates to immersion lithography.

Background

[0003] The term "patterning device" as here employed should be broadly interpreted as referring to means that can be used to endow an incoming radiation beam with a patterned cross-section, corresponding to a pattern that is to be created in a target portion of the substrate; the term "light valve" can also be used in this context. Generally, the said pattern will correspond to a particular functional layer in a device being created in the target portion, such as an integrated circuit or other device (see below). Examples of such a patterning device include:

[0004] - A mask. The concept of a mask is well known in lithography, and it includes mask types such as binary, alternating phase-shift, and attenuated phase-shift, as well as various hybrid mask types. Placement of such a mask in the radiation beam causes selective transmission (in the case of a transmissive mask) or reflection (in the case of a reflective mask) of the radiation impinging on the mask, according to the pattern on the mask. In the case of a mask, the support structure will generally be a mask table, which ensures that the mask can be held at a desired position in the incoming radiation beam, and that it can be moved relative to the beam if so desired.

[0005] - A programmable mirror array. One example of such a device is a matrix-addressable surface having a viscoelastic control layer and a reflective surface. The basic principle behind such an apparatus is that (for example) addressed areas of the reflective surface reflect incident light as diffracted light, whereas unaddressed areas reflect incident light as undiffracted light. Using an appropriate filter, the said undiffracted light can be filtered out of the reflected beam, leaving only the diffracted light behind; in this manner, the beam becomes patterned according to the addressing pattern of the matrix-addressable surface. An

alternative embodiment of a programmable mirror array employs a matrix arrangement of tiny mirrors, each of which can be individually tilted about an axis by applying a suitable localized electric field, or by employing piezoelectric actuation means. Once again, the mirrors are matrix-addressable, such that addressed mirrors will reflect an incoming radiation beam in a different direction to unaddressed mirrors; in this manner, the reflected beam is patterned according to the addressing pattern of the matrix-addressable mirrors. The required matrix addressing can be performed using suitable electronic means. In both of the situations described hereabove, the patterning device can comprise one or more programmable mirror arrays. More information on mirror arrays as here referred to can be gleaned, for example, from United States patents US 5,296,891 and US 5,523,193, and PCT patent applications WO 98/38597 and WO 98/33096, which are incorporated herein by reference. In the case of a programmable mirror array, the said support structure may be embodied as a frame or table, for example, which may be fixed or movable as required.

[0006] - A programmable LCD array. An example of such a construction is given in United States patent US 5,229,872, which is incorporated herein by reference. As above, the support structure in this case may be embodied as a frame or table, for example, which may be fixed or movable as required.

[0007] For purposes of simplicity, the rest of this text may, at certain locations, specifically direct itself to examples involving a mask and mask table; however, the general principles discussed in such instances should be seen in the broader context of the patterning device as hereabove set forth.

[0008] Lithographic projection apparatus can be used, for example, in the manufacture of integrated circuits (ICs). In such a case, the patterning device may generate a circuit pattern corresponding to an individual layer of the IC, and this pattern can be imaged onto a target portion (*e.g.* comprising one or more dies) on a substrate (silicon wafer) that has been coated with a layer of radiation-sensitive material (resist). In general, a single wafer will contain a whole network of adjacent target portions that are successively irradiated via the projection system, one at a time. In current apparatus, employing patterning by a mask on a mask table, a distinction can be made between two different types of machine. In one type of lithographic projection apparatus, each target portion is irradiated by exposing the entire mask pattern onto the target portion at one time; such an apparatus is commonly referred to as a wafer stepper. In an alternative apparatus - commonly referred to as a step-and-scan apparatus -

each target portion is irradiated by progressively scanning the mask pattern under the projection beam in a given reference direction (the "scanning" direction) while synchronously scanning the substrate table parallel or anti-parallel to this direction; since, in general, the projection system will have a magnification factor M (generally < 1), the speed V at which the substrate table is scanned will be a factor M times that at which the mask table is scanned. More information with regard to lithographic devices as here described can be gleaned, for example, from United States patent US 6,046,792, incorporated herein by reference.

[0009] In a manufacturing process using a lithographic projection apparatus, a pattern (e.g. in a mask) is imaged onto a substrate that is at least partially covered by a layer of radiation-sensitive material (resist). Prior to this imaging step, the substrate may undergo various procedures, such as priming, resist coating and a soft bake. After exposure, the substrate may be subjected to other procedures, such as a post-exposure bake (PEB), development, a hard bake and measurement/inspection of the imaged features. This array of procedures is used as a basis to pattern an individual layer of a device, e.g. an IC. Such a patterned layer may then undergo various processes such as etching, ion-implantation (doping), metallization, oxidation, chemo-mechanical polishing, etc., all intended to finish off an individual layer. If several layers are required, then the whole procedure, or a variant thereof, will have to be repeated for each new layer. Eventually, an array of devices will be present on the substrate (wafer). These devices are then separated from one another by a technique such as dicing or sawing, whence the individual devices can be mounted on a carrier, connected to pins, etc. Further information regarding such processes can be obtained, for example, from the book "Microchip Fabrication: A Practical Guide to Semiconductor Processing", Third Edition, by Peter van Zant, McGraw Hill Publishing Co., 1997, ISBN 0-07-067250-4, incorporated herein by reference.

[0010] For the sake of simplicity, the projection system may hereinafter be referred to as the "lens"; however, this term should be broadly interpreted as encompassing various types of projection system, including refractive optics, reflective optics, and catadioptric systems, for example. The radiation system may also include components operating according to any of these design types for directing, shaping or controlling the projection beam of radiation, and such components may also be referred to below, collectively or singularly, as a "lens". Further, the lithographic apparatus may be of a type having two or more substrate tables (and/or two or more mask tables). In such "multiple stage" devices the additional tables may be used in

parallel, or preparatory steps may be carried out on one or more tables while one or more other tables are being used for exposures. Dual stage lithographic apparatus are described, for example, in United States patent US 5,969,441 and PCT patent application WO 98/40791, incorporated herein by reference.

[0011] It has been proposed to immerse the substrate in the lithographic projection apparatus in a liquid having a relatively high refractive index, e.g. water so as to fill a space between the final element of the projection system and the substrate. The point of this is to enable imaging of smaller features as the exposure radiation will have a shorter wavelength in the liquid. (The effect of the liquid may also be regarded as increasing the effective NA of the system and also increasing the depth of focus.)

[0012] However, submersing the substrate or substrate and substrate table in a bath of liquid (see for example United States patent US 4,509,852, hereby incorporated in its entirety by reference) may mean that there is a large body of liquid that must be accelerated during a scanning exposure. This may require additional or more powerful motors and turbulence in the liquid may lead to undesirable and unpredictable effects.

[0013] One of the solutions proposed is for a liquid supply system to provide liquid on only a localized area of the substrate and in between the final element of the projection system and the substrate (the substrate generally has a larger surface area than the final element of the projection system). One way which has been proposed to arrange for this is disclosed in PCT patent application WO 99/49504, hereby incorporated in its entirety by reference. As illustrated in Figures 9 and 10, liquid is supplied by at least one inlet IN onto the substrate, preferably along the direction of movement of the substrate relative to the final element, and is removed by at least one outlet OUT after having passed under the projection system. That is, as the substrate is scanned beneath the element in a –X direction, liquid is supplied at the +X side of the element and taken up at the –X side. Figure 9 shows the arrangement schematically in which liquid is supplied via inlet IN and is taken up on the other side of the element by outlet OUT which is connected to a low pressure source. In the illustration of Figure 9 the liquid is supplied along the direction of movement of the substrate relative to the final element, though this does not need to be the case. Various orientations and numbers of in- and out-lets positioned around the final element are possible, one example is illustrated in Figure 10 in which four sets of an inlet with an outlet on either side are provided in a regular pattern around the final element.

Summary

[0014] With such and other arrangements for providing liquid on only a localized area of the substrate, the substrate itself acts to contain the liquid of the liquid supply system in a space between the final element of the projection system and the substrate. If the substrate is removed (for example, during substrate exchange) and no other measures are taken, the liquid will run out of the liquid supply system. Clearly this is a situation which is to be avoided. The liquid can be removed from the space before the substrate is moved. However, as the residue of liquid which is inevitably left behind when the liquid supply system is emptied of liquid, dries, drying spots may be left behind on elements of the projection system which were immersed in the liquid during exposure. This may be clearly detrimental to the continuing high performance of the projection system. Also, on refilling the space with liquid, it may be hard to avoid the formation of bubbles. Filling of the space with liquid will also take time and may reduce throughput time.

[0015] Accordingly, it may be advantageous to provide, for example, a lithographic projection apparatus in which immersion lithography can be performed and in which removing liquid from the liquid supply system during substrate exchange can be avoided or reduced.

[0016] According to an aspect, there is provided a lithographic projection apparatus comprising:

[0017] a support structure configured to hold a patterning device, the patterning device configured to pattern a beam of radiation according to a desired pattern;

[0018] a substrate table configured to hold a substrate;

[0019] a projection system configured to project the patterned beam onto a target portion of the substrate;

[0020] a liquid supply system configured to provide an immersion liquid, through which said beam is to be projected, in a space between said projection system and said substrate; and

[0021] a shutter configured to keep said projection system in contact with liquid when said substrate is moved away from under said projection system.

[0022] In this way drying marks on the projection system can be avoided. This solution is ideal for a localized area liquid supply system which provides immersion liquid to

only a localized area of the substrate. One arrangement could involve one or more jets to project liquid onto the projection system during substrate swap.

[0023] In an embodiment, there is provided a shutter positionable on a side of said liquid supply system opposite said projection system such that liquid can be confined in said liquid supply system and between said projection system and said shutter. With this arrangement, for example, the shutter can be moved under the liquid supply system after exposure of the substrate in order to contain the immersion liquid. The substrate may then be moved from the substrate table without substantially losing liquid from the liquid supply system, because the shutter takes the place of the substrate and is of a size equal to or greater than the localized area so that liquid can't substantially escape between the projection system and the shutter.

[0024] In an embodiment, the shutter comprises a surface of said substrate table. With this arrangement, the substrate table is moved after exposure to a position at which the substrate may be removed but also to a position at which the shutter is positioned over the liquid supply system. A seal, such as a gas seal, which can also be used to seal a liquid confinement structure that extends along at least a part of the boundary of said space to contain liquid and that forms an aperture for said patterned beam to pass through to the substrate during exposure, can remain activated to seal between the liquid supply system and the shutter. The shutter blocks the aperture. Alternatively, the shutter may be raised relative to the structure to abut the structure and the seal can then be de-activated.

[0025] In an embodiment, the shutter is separable from the remainder of the apparatus. It is also movable relative to the remainder of the apparatus. That is, the shutter is relatively small, perhaps shaped like a plate, and not permanently attached to other parts of the apparatus. In this embodiment, the substrate table can be moved completely away from the liquid supply system after exposure as the shutter is positioned over the liquid supply system and is independent of the substrate table. In this embodiment the shutter can be carried by the substrate table during exposure and to this end the shutter and/or the substrate table has or have a holding device configured to releasably hold the shutter to the substrate table. Also, an attachment device may be provided to releasably attach the shutter to the liquid supply system. The attachment device or the holding device may comprise a magnet to generate the force required to attach or hold. Alternatively, those devices may comprise a vacuum outlet configured to attract the shutter to the substrate table and/or the liquid supply system. In the

case of the attachment device, use may be made of a gas seal configured to seal between the liquid supply system and the substrate during exposure in order to provide the force to attach the shutter to the liquid supply system.

[0026] In an embodiment, the liquid supply system comprises an outlet configured to remove liquid from the space and a gas inlet configured to provide flushing gas in said space. Flushing might be required every now and again due to contamination of the liquid or perhaps during a long term shut down of the apparatus. In this way, liquid may be removed from the space and the space can be flushed with gas. The shutter is then attached to the aperture to protect the projection system.

[0027] In an embodiment, the liquid supply system is configured to provide said liquid to a space between a final lens of said projection system and said substrate.

[0028] According to an aspect, there is provided a device manufacturing method comprising:

[0029] providing an immersion liquid to a space between a projection system and a substrate;

[0030] projecting a patterned beam of radiation, through said liquid, onto a target portion of the substrate using the projection system; and

[0031] maintaining said projection system in contact with liquid after said substrate has been moved away from under said projection system.

[0032] Although specific reference may be made in this text to the use of the apparatus described herein in the manufacture of ICs, it should be explicitly understood that such an apparatus has many other possible applications. For example, it may be employed in the manufacture of integrated optical systems, guidance and detection patterns for magnetic domain memories, liquid-crystal display panels, thin-film magnetic heads, etc. The skilled artisan will appreciate that, in the context of such alternative applications, any use of the terms "reticle", "wafer" or "die" in this text should be considered as being replaced by the more general terms "mask", "substrate" and "target portion", respectively.

[0033] In the present document, the terms “radiation” and “beam” are used to encompass all types of electromagnetic radiation, including ultraviolet radiation (*e.g.* with a wavelength of 365, 248, 193, 157 or 126 nm).

Brief Description of the Drawings

[0034] Embodiments of the invention will now be described, by way of example only, with reference to the accompanying schematic drawings in which:

[0035] Figure 1 depicts a lithographic projection apparatus according to an embodiment of the invention;

[0036] Figure 2 depicts the liquid reservoir of a first embodiment of the invention;

[0037] Figure 3 depicts the liquid reservoir and substrate table of the first embodiment of the invention;

[0038] Figure 4 depicts the liquid reservoir, substrate table and shutter member of a second embodiment of the invention;

[0039] Figure 5 depicts the liquid reservoir, substrate table and shutter member of the second embodiment of the present invention;

[0040] Figure 6 illustrates an alternative arrangement of the second embodiment of liquid reservoir, substrate table and shutter member of the present invention;

[0041] Figure 7 illustrates a third embodiment of the present invention;

[0042] Figure 8 illustrates a variant of the third embodiment;

[0043] Figure 9 illustrates an alternative liquid supply system according to an embodiment of the invention; and

[0044] Figure 10 illustrates, in plan, the system of Figure 9.

[0045] In the Figures, corresponding reference symbols indicate corresponding parts.

Detailed Description

Embodiment 1

[0046] Figure 1 schematically depicts a lithographic projection apparatus according to a particular embodiment of the invention. The apparatus comprises:

[0047] · a radiation system Ex, IL, for supplying a projection beam PB of radiation (*e.g.* UV radiation), which in this particular case also comprises a radiation source LA;

[0048] · a first object table (mask table) MT provided with a mask holder for holding a mask MA (*e.g.* a reticle), and connected to first positioning means for accurately positioning the mask with respect to item PL;

[0049] · a second object table (substrate table) WT provided with a substrate holder for holding a substrate W (*e.g.* a resist-coated silicon wafer), and connected to second positioning means for accurately positioning the substrate with respect to item PL;

[0050] · a projection system ("lens") PL (*e.g.* a refractive lens system) for imaging an irradiated portion of the mask MA onto a target portion C (*e.g.* comprising one or more dies) of the substrate W.

[0051] As here depicted, the apparatus is of a transmissive (*e.g.* has a transmissive mask). However, in general, it may also be of a reflective type, for example (*e.g.* with a reflective mask). Alternatively, the apparatus may employ another kind of patterning device, such as a programmable mirror array of a type as referred to above.

[0052] The source LA (*e.g.* an excimer laser) produces a beam of radiation. This beam is fed into an illumination system (illuminator) IL, either directly or after having traversed conditioning means, such as a beam expander Ex, for example. The illuminator IL may comprise adjusting means AM for setting the outer and/or inner radial extent (commonly referred to as σ-outer and σ-inner, respectively) of the intensity distribution in the beam. In addition, it will generally comprise various other components, such as an integrator IN and a condenser CO. In this way, the beam PB impinging on the mask MA has a desired uniformity and intensity distribution in its cross-section.

[0053] It should be noted with regard to Figure 1 that the source LA may be within the housing of the lithographic projection apparatus (as is often the case when the source LA is a mercury lamp, for example), but that it may also be remote from the lithographic projection apparatus, the radiation beam which it produces being led into the apparatus (e.g. with the aid of suitable directing mirrors); this latter scenario is often the case when the source LA is an excimer laser. The current invention and claims encompass both of these scenarios.

[0054] The beam PB subsequently intercepts the mask MA, which is held on a mask table MT. Having been selectively reflected by the mask MA, the beam PB passes through the lens PL, which focuses the beam PB onto a target portion C of the substrate W. With the aid of the second positioning means (and interferometric measuring means IF), the substrate table WT can be moved accurately, *e.g.* so as to position different target portions C in the path of the beam PB. Similarly, the first positioning means can be used to accurately position the mask MA with respect to the path of the beam PB, *e.g.* after mechanical retrieval of the mask MA from a mask library, or during a scan. In general, movement of the object tables MT, WT will

be realized with the aid of a long-stroke module (course positioning) and a short-stroke module (fine positioning), which are not explicitly depicted in Figure 1. However, in the case of a wafer stepper (as opposed to a step-and-scan apparatus) the mask table MT may just be connected to a short stroke actuator, or may be fixed.

[0055] The depicted apparatus can be used in two different modes:

[0056] 1. In step mode, the mask table MT is kept essentially stationary, and an entire mask image is projected at one time (*i.e.* a single "flash") onto a target portion C. The substrate table WT is then shifted in the x and/or y directions so that a different target portion C can be irradiated by the beam PB;

[0057] 2. In scan mode, essentially the same scenario applies, except that a given target portion C is not exposed in a single "flash". Instead, the mask table MT is movable in a given direction (the so-called "scan direction", *e.g.* the y direction) with a speed v, so that the projection beam PB is caused to scan over a mask image; concurrently, the substrate table WT is simultaneously moved in the same or opposite direction at a speed $V = Mv$, in which M is the magnification of the lens PL (typically, $M = 1/4$ or $1/5$). In this manner, a relatively large target portion C can be exposed, without having to compromise on resolution.

[0058] Figure 2 shows a liquid reservoir 10 between the projection system PL and the substrate W which is positioned on the substrate stage WT. The liquid reservoir 10 is filled with a liquid 11 having a relatively high refractive index, e.g. water, provided via inlet/outlet ducts 13. The liquid has the effect that the radiation of the projection beam is a shorter wavelength in the liquid than in air or in a vacuum, allowing smaller features to be resolved. It is well known that the resolution limit of a projection system is determined, inter alia, by the wavelength of the projection beam and the numerical aperture of the system. The presence of the liquid may also be regarded as increasing the effective numerical aperture. Furthermore, at fixed numerical aperture, the liquid is effective to increase the depth of focus.

[0059] The reservoir 10 forms, in an embodiment, a contactless seal to the substrate W around the image field of the projection lens PL so that the liquid is confined to fill the space between the substrate's primary surface, which faces the projection system PL, and the final optical element of the projection system PL. The reservoir is formed by a seal member 12 positioned below and surrounding the final element of the projection lens PL. Thus, the liquid supply system provides liquid on only a localized area of the substrate. The seal member 12 forms part of the liquid supply system for filling the space between the final element of the

projection system and the substrate W with a liquid. This liquid is brought into the space below the projection lens and within the seal member 12. The seal member 12 extends a little above the bottom element of the projection lens and the liquid rises above the final element so that a buffer of liquid is provided. The seal member 12 has an inner periphery that at the upper end closely conforms to the shape of the projection system or the final elements thereof and may, e.g. be round. At the bottom the inner periphery forms an aperture which closely conforms to the shape of the image field, e.g. rectangular, though this is not necessarily so. The projection beam passes through this aperture.

[0060] The liquid 11 is confined in the reservoir 10 by a seal 16. As illustrated in Figure 2, the seal is a contactless seal, i.e. a gas seal. The gas seal is formed by gas, e.g. air or synthetic air, provided under pressure via inlet 15 to the gap between seal member 12 and substrate W and extracted by first outlet 14. The over pressure on the gas inlet 15, vacuum level on the first outlet 14 and the geometry of the gap are arranged so that there is a high-velocity gas flow inwards towards the optical axis of the apparatus that confines the liquid 11. As with any seal, some liquid is likely to escape, for example up the first outlet 14.

[0061] Figures 9 and 10 also depict a liquid reservoir defined by inlet(s) IN, outlet(s) OUT, the substrate W and the final element of projection lens PL. Like the liquid supply system of Figure 2 the liquid supply system illustrated in Figures 9 and 10, comprising inlet(s) IN and outlet(s) OUT, supplies liquid to a space between the final element of the projection system and a localized area of the primary surface of the substrate.

[0062] As can be seen from Figures 2 and 9, during exposure, the substrate W provides the bottom wall of the liquid reservoir thereby containing the liquid in a space between the projection system PL and the substrate W.

[0063] Figure 3 shows the substrate table WT according to a first embodiment which can be used to avoid the necessity of emptying liquid from the liquid reservoir once the substrate W has been imaged and before being unloaded from the substrate table WT. A shutter member 100 (also termed a cover plate, edge seal member, gap seal means or member or intermediary plate) is provided for this purpose. The shutter member 100 is a surface other than a substrate surface, in this case an upper (as illustrated) primary surface of the substrate table WT which is substantially co-planar with the upper primary surface of the substrate W and is closely adjacent to the edge of the substrate W. The area of the shutter member 100 is large enough so that if the substrate table WT is moved such that the projection system PL and

seal member 12 are positioned over the shutter member 100 (as illustrated in dotted lines) the shutter member blocks the entire aperture of the seal member 12 to prevent liquid escaping through the aperture. In this position, the substrate W can be removed from the substrate table WT using usual substrate handling equipment. If the edge of the substrate W is close to the edge of the shutter member 100 (i.e. the gap between the substrate W, when positioned on the pimple table or chuck or whatever holds the substrate W to the substrate table WT, and the edge of the shutter member 100 is relatively small), there will be no sudden loss of liquid as the edge of the substrate moves under the aperture in the seal member 12. The substrate table WT may be raised towards the projection system to block the aperture so that the seal 16 can be deactivated.

Embodiment 2

[0064] A second embodiment is illustrated in Figure 4 and allows the substrate table WT to be moved completely away from the projection system PL and seal member 12 in order for the substrate W to be removed from the substrate table WT and a new substrate to be placed on the substrate table WT. Thus it can be used, for example, with dual stage machines.

[0065] In the second embodiment, a shutter member 150 is in the form of a plate with a primary cross-sectional area larger than that of the localized area or aperture in the seal member 12. The shape of the shutter member 150 may be any shape so long as it covers the aperture. The shutter member 150 is not a substrate and is movable relative to both the substrate table WT and the seal member 12 and may be attached to the seal member 12 by any means, two examples of which are described below.

[0066] After imaging of the substrate W, the substrate table WT is moved so that the shutter member 150 is positioned under the aperture of the seal member 12. The gap between the substrate W and the top surface of the substrate table WT and the gap between the top of the substrate table WT and the top surface of the shutter member 150 are small so there is no catastrophic loss of liquid from the reservoir 10 while passing over the gaps. The top (primary) surfaces (as illustrated) of the substrate W, substrate table WT between the substrate W and the shutter member 150 and the shutter member 150 are arranged to be substantially co-planar. Once positioned under the projection system PL, the shutter member 150 is attached to the bottom of the seal member 12 to cover the aperture. The seal member 12 is then moved away from the substrate table WT in the Z direction (the direction of the optical axis) or the substrate

table WT is lowered away from the seal member 12. The substrate table WT may then be moved out of the way to a place where the substrate W may be exchanged. Once a new substrate has been loaded onto the substrate table WT and any necessary alignment or other measurements (e.g. leveling) have been made (e.g. in a dual stage machine), the substrate table WT is moved to a position where the shutter member 150 may be re-positioned onto the substrate table WT and then the substrate table WT is moved such that the substrate W is positioned under the projection system PL so that exposure can begin.

[0067] Of course it may be possible to provide the shutter member 150 on an object in the lithographic apparatus other than the substrate table WT. For example, a robotic arm can be provided which moves to position the shutter member under the projection system after exposure.

[0068] The position of the shutter member 150 may drift over time so that means for centering or at least keeping a track of the position of the shutter member is useful. This may be a mechanical or optical or electrical or other type of sensor on the landing area of the shutter member on the substrate table WT and/or such a sensor provided on the liquid supply system (e.g. seal member 12). For such a system, a quartz shutter member is desired, especially for an apparatus which exposes at 193 nm. Alternatively or additionally, a through lens sensor and detector that uses a reflected signal from a marker on the shutter member 150 which signal is coupled via a beam splitter to the detector is provided. Such a system can be used while the substrate stage WT is moving, thereby improving throughput. Alternatively or additionally, the position of the shutter member may be measured by an optical sensor on the substrate table WT. In this case a mark is applied to the underside or top side of the shutter member 150 (e.g. a transmissive pattern for the radiation wavelength) and the position of the shutter member 150 may then be measured by a sensor on the substrate table WT while the projection system PL exposes the mark. The mark is transmissive to radiation from the projection system (or another radiation source) and a transmission image sensor (TIS) or spot-sensor which is on the substrate table WT can then be used to measure displacement of the shutter member when attached to the liquid supply system. Depending on the mark design on the shutter member, the transmission image sensor (TIS) or spot sensor that is already available in the substrate table WT can be used. In this way, the apparatus can keep a record of the drift in position of the shutter member over time by sensing the position regularly, for example every cycle or perhaps

only every ten or one hundred cycles or when is deemed necessary. Any necessary adjustments can then be made.

[0069] Alternatively, a quad cell sensor can be mounted at the center of the shutter member 150. An absorbing (or transmissive) spot is positioned in the center of the mirror block so that when the shutter member 150 is positioned on the substrate stage WT after use, its position can be measured. The quad cell sensor is made up of four light sensitive cells in a square. When the light beam is on center the outputs of the four cells are equal. If the sensor drifts to one side, the outputs of the cells on that side increase compared to the cells or the other side. Thus any deviation from the desired position can be corrected the next time the shutter member 150 is attached to the liquid supply system.

[0070] Another way of centering the shutter member 150, which does not involve complicated positional sensing, is to provide the shutter member 150 with a shape which is self centering when picked up by the liquid supply system. A suitable example might be a thicker shutter member 150 than is needed with a conical edge that locates in the aperture of the liquid supply system.

[0071] Figure 5 illustrates one way of attaching the shutter member 150 to the underside of the seal member 12. This method usefully makes use of the seal 16 of the seal member 12. The outlet 14 is energized and the (gas) inlet 15 is not energized when the shutter member 150 is positioned under the aperture. The vacuum provided in the outlet 14 is enough to attract the shutter member 150 to be clamped to the bottom of the seal member 12 thereby sealing the aperture. When the shutter member 150 is replaced on the substrate table WT, the seal 16 can be reactivated to operate as normal and the substrate table WT moved to the expose position. The shutter member 150 may be held on the substrate table WT by use of vacuum outlet 157 connected to a vacuum source through a duct 155. To avoid or reduce immersion liquid leakage under the shutter member 150, a (annular) channel 158 is provided around the vacuum outlet 157. The channel 158 is connected via a duct 159 to a vacuum source so that any liquid is removed by the flow of gas through the channel 158 caused by the vacuum. It might be advantageous to have a flow of gas in the channel 158, even when the shutter member 150 is in place. To this end a duct 156 open at a surface, for example the top surface of the substrate table WT, and connected to the channel 158 can be provided on a side substantially opposite to the duct 159 leading to the vacuum source. In the second

embodiment, the seal 16 need not be activated while the shutter member 150 is positioned to cover the aperture but, in an embodiment, is activated.

[0072] An alternative means for holding the shutter member 150 to the substrate table WT and means for attaching the shutter member 150 to the seal member 12, is illustrated in Figure 6. In this embodiment the shutter member 150 is made of a ferromagnetic material (or partly of ferromagnetic material by making an assy) such that magnets 160, 170 (in an embodiment, electromagnets for easy attachment and detachment) positioned on the seal member 12 and substrate table WT may be used to hold the shutter member 150 in position against the seal member 12 and substrate table WT respectively. By keeping seal 16 activated, loss of liquid can be minimized. The channel 158 and duct 156, 159 arrangement described in relation to the Figure 5 embodiment may also be employed in the Figure 6 embodiment to reduce or alleviate liquid leakage under the shutter member 150.

[0073] The shutter member 150 should be held by at least one of the substrate table WT and the seal member 12 so that the shutter member 150 is under control.

[0074] As it is further illustrated in Figure 6, it may be desirable to remove liquid 11 from the reservoir 10 during substrate exchange. This is done by extracting the liquid either through the outlet 14 or the outlet duct 13 (see, e.g., Figures 5 and 2 respective) and then flushing the space with gas provided through a further gas inlet 17. This might be done for maintenance and the lens may need to be cleaned after this process.

[0075] Of course, features from both Figures 5 and 6 can be combined.

Embodiment 3

[0076] A third embodiment is the same as the second embodiment except as described below. The third embodiment is illustrated in Figure 7 and differs from the second embodiment in that the shutter member 150 is placed within the seal member 12. The similarity with the second embodiment lies in the fact that the shutter member is separate from the substrate table WT. The shutter member 150 can be moved from any resting position to block the aperture by being moved under the projection system PL through channels 250 in the seal member 12.

[0077] The shutter member 150 may either be separate from the seal member 12 and moved into the seal member 12 at the required time by a robotic arm, for example, or the shutter member may have a series of leafs 300 as illustrated in Figure 8. The leafs 300 work

like a shutter of a camera in that the leafs can be moved such that they do not obstruct the aperture but, when the plurality of leafs are moved to abut at the center of the aperture they thereby block the aperture.

[0078] The embodiments herein have been described in relation to the seal member variant of the localized area solution. However, the embodiments as described herein are equally applicable to any other type of liquid supply for example those disclosed in European Patent application nos. 03254078.3 or 03256643.2 hereby incorporated in their entirety by reference or to the variant illustrated in Figures 9 and 10. For example, in the case of a shutter member 150 moveable relative to both the substrate table WT and the projection system PL, means for attaching the shutter member below the in-and outlets IN, OUT may be attached to the members forming the in-and-out-lets IN, OUT, or to a separate structure. Additionally or alternatively, the vacuum of the outlets OUT can be used to attract the shutter member to the IN-and outlets IN, OUT and thereby seal the aperture. It may be desirable to use a non-flat shutter member e.g. one with a protruding border so that any drips of liquid from the various in-and out-lets are contained. Any system for generating a force can be used for the means for attaching, including low pressure sources, magnetic means, mechanical means, electro static means, etc.

[0079] While specific embodiments of the invention have been described above, it will be appreciated that the invention may be practiced otherwise than as described. The description is not intended to limit the invention.